UNCLASSIFIED MASTER COPY - FOR REPRODUCTION PURPOSES

SECURITY CLASSIFICATION OF THIS PAGE

AD-A204 441

REPORT DOCUMENTATION PAGE

1b. RESTRICTIVE MARKINGS DTIC FILE COPY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release; distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)

5. MONITORING ORGANIZATION REPORT NUMBER(S)
ARO 22981.2-EL

6a. NAME OF PERFORMING ORGANIZATION
Pennsylvania State Univ.

6b. OFFICE SYMBOL (If applicable)

7a. NAME OF MONITORING ORGANIZATION
U. S. Army Research Office

6c. ADDRESS (City, State, and ZIP Code)
University Park, PA 16802

7b. ADDRESS (City, State, and ZIP Code)
P. O. Box 12211
Research Triangle Park, NC 27709-2211

8a. NAME OF FUNDING / SPONSORING ORGANIZATION
U. S. Army Research Office

8b. OFFICE SYMBOL (If applicable)

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
DAAG29-85-K-0179

8c. ADDRESS (City, State, and ZIP Code)
P. O. Box 12211
Research Triangle Park, NC 27709-2211

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Spread Spectrum Propagation Prediction

12. PERSONAL AUTHOR(S)
Raymond Luebbers

13a. TYPE OF REPORT
Final

13b. TIME COVERED
FROM 7/15/85 TO 12/31/88

14. DATE OF REPORT (Year, Month, Day)
February 1989

15. PAGE COUNT
6

16. SUPPLEMENTARY NOTATION
The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
GTD Propagation Model, Wideband Signal Propagation
Terrain Reflection, Teometrical Theory of Diffraction(GTD)
Terrain Diffraction, Terrain Profiles

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

In order to efficiently model effects of terrain on wideband radio signals several basic improvements to the Geometrical Theory of Diffraction (GTD) propagation model were made.

As a result of this effort a terrain sensitive propagation model capable of predicting the wideband channel transfer function, including the important channel characterization parameters, has been developed and validated against measurements. In addition, significant advances in the Geometrical Theory of Diffraction, both in general and as applied to radio propagation prediction, have been made.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL

22b. TELEPHONE (Include Area Code)

22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted.
All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

ARO 22981.2-EL

SPREAD SPECTRUM PROPAGATION PREDICTION

Final Technical Report

Raymond Luebbers

February 1989

U. S. ARMY RESEARCH OFFICE

RESEARCH AGREEMENT NO. DAAG29-85-K-0179

Communications and Space Sciences Laboratory
Department of Electrical Engineering
The Pennsylvania State University
University Park, PA 16802

STATEMENT OF THE PROBLEM STUDIED

The goal of this effort was to provide the theoretical and computational means to efficiently and accurately predict the effects of intervening terrain on the propagation of wideband signals. The important channel parameters to predict include the complex frequency-domain channel transfer function, wideband received signal level, impulse response, multipath amplitude, delay, and delay spread. In meeting this goal the following work was anticipated.

The geometrical theory of diffraction (GTD), as it had been applied to terrain reflection and diffraction, required that the 2-dimensional terrain profile be approximated as piecewise-linear. An algorithm to automatically construct from the actual (digitized) terrain profile the optimum linearized profile was to be developed.

The GTD was not generally valid when applied to multiple wedge diffraction, which resulted in reduced accuracy. This error source was to be reduced or eliminated for accurate results in all terrain situations. The GTD also has accuracy limitations when applied to lossy wedges. These were also to be reduced or eliminated for more accurate results.

An algorithm for efficiently finding and evaluating the important GTD rays for a general terrain profile as the frequency is varied was to be developed, and used to generate the complex frequency domain channel transfer function describing the propagation effects.

An algorithm for efficiently transferring the frequency domain channel transfer function to the time domain in a format suitable for channel characterization and comparison with measurement was to be developed based on the fast Fourier transform.

The theoretical results obtained from the above were to be compared with measured results to be made available from a separate Army wideband channel measurement program. This involved interaction with the measurement program in such areas as site selection, measurement techniques, and channel characterization parameters.

It was hoped and anticipated that publications would result containing new information on wideband signal propagation of general usefulness.

SUMMARY OF THE MOST IMPORTANT RESULTS

In order to efficiently model effects of terrain on wideband radio signals several basic improvements to the GTD propagation model were made. An algorithm for automatically generating the piece-wise linear approximation to the actual terrain profile was developed. Also, the algorithm for finding the existing rays was modified so as to be more efficient when analyzing wideband signals. The existing rays were found only for the first frequency, and these particular rays were automatically reused at the other frequencies within the wideband signal without repeating the existence algorithm for each subsequent frequency.

The GTD lossy wedge diffraction coefficients were investigated for accuracy by comparison with other methods, and a lossy wedge slope diffraction coefficient was developed.

The most important GTD development was the synthesis of a general uniform double wedge diffraction coefficient. This had been sought by other researchers for a number of years without success, and its inclusion in the GTD propagation model greatly increases the accuracy and general applicability of the model.

While the theoretical basis of the GTD propagation model received the improvements described above, significant effort was expended in extending the capability of the model to included wideband signals. The basic results of the frequency domain GTD path loss computations were transformed to the time domain in such a way as to simulate the Wideband Propagation Measurement System (WPMS) built and used by SRI International. The transformed GTD model simulations of wideband path loss were directly comparable with the measured WPMS data. Terrain effects on channel parameters such as the bandlimited channel impulse response, wideband received signal level, multipath amplitude, delay, and delay spread, and coherence bandwidth were made available from the GTD model as a result of this effort.

In order to obtain WPMS measured data for validation of the GTD wideband propagation model the principal investigator interacted with appropriate SRI International employees in the measurement site selection process, and traveled to the measurement sites while measurements were being made.

In general the GTD model prediction capability was validated by the SRI measurements, as reported in the literature.

As a result of this effort a terrain sensitive propagation model capable of predicting the wideband channel transfer function, including the important channel characterization parameters, has been developed and validated against measurements. In addition, significant advances in the Geometrical Theory of Diffraction, both in general and as applied to radio propagation prediction, have been made.

LIST OF ALL PUBLICATIONS

W. Foose, "Wideband Propagation Prediction Using the Geometrical Theory of Diffraction," Master's Degree Thesis, December 1986.

M. Schneider, "A Uniform Solution of Double Knife Edge Diffraction," Master's Degree Thesis, December 1987.

G. Reyner, "An Analysis of Multipath Power Delay Profiles," Master's Degree Thesis, May 1988.

M. Schneider, "A Uniform Solution of Double Wedge Diffraction," PhD Degree Dissertation, December 1988.

Luebbers, R., "Comparison of Lossy Wedge Diffraction Coefficients with Application to Mixed Path Propagation Loss Prediction," IEEE Transactions on Antennas and Propagation, Vol. AP-36:9, pp. 1031-1034, July 1988.

Luebbers, R., "A Heuristic UTD Slope Diffraction Coefficient for Rough Lossy Wedges," accepted for publication in IEEE Transactions on Antennas and Propagation, February 1989.

Luebbers, R., W. Foose and G. Reyner, "Comparison of GTD Propagation Model Wideband Path Loss Simulation with Measurements," accepted for publication in IEEE Transactions on Antennas and Propagation, April 1989.

Luebbers, R., W. Foose and G. Reyner, "Comparison of GTD Propagation Model Wideband Path Loss Simulation with Measurements," accepted for publication in IEEE Transactions on Antennas and Propagation, April 1989.

Luebbers, R. J., "A Semi-Blind Test of the GTD Propagation Model for Reflective Rolling Terrain," accepted for publication in IEEE Transactions on Antennas and Propagation.

Luebbers, R. J., G. Reyner and W. Foose, "Comparison of the GTD Propagation Model Wideband Pseudo-Noise Simulation with Measurements over a Diffraction Path," submitted to IEEE Transactions on Communications, July 1988.

Schneider, M. and R. J. Luebbers, "On a Series Appearing in Double Knife Edge Diffraction," submitted to Radio Science, August 1988.

Schneider, M. and R. Luebbers, "A General, Uniform Double Wedge Diffraction Coefficient," submitted to IEEE Transactions on Antennas and Propagation, December 1989.

Luebbers, R., "Prediction of Wide-Bandwidth Radio Transmission Loss Over Irregular Terrain," International Symposium on Antennas and Propagation, Kyoto, Japan, August 1985.

Luebbers, R., "Prediction of Terrain Effects on Radio Propagation Using GTD," Society of Engineering Sciences 22nd Annual Meeting, The Pennsylvania State University, October 1985.

Luebbers, R. and W. Foose, "Prediction of Wide-bandwidth Time-domain Radio Transmission Loss over Irregular Terrain," IEEE AP-S/URSI Symposium, Philadelphia, PA, June 1986.

Luebbers, R., "Application of GTD Propagation Model to Prediction of Wideband Channel Delay, Delay Spread, and Received Signal Level," IEEE AP-S/URSI Symposium, Blacksburg, VA, June 1987.

Luebbers, R., "The GTD Terrain Model," Invited Tutorial Paper presented at IEEE/AFCEA Information Systems Technology IV Symposium, Fort Huachara, AZ, October 8, 1987.

Luebbers, R. and G. Reyner, "GTD Predictions of Terrain Effects on Wideband Channel Delay, Coherence Bandwidth, and Received Signal Level for a Diffraction Path," IEEE AP-S/URSI Symposium, Syracuse, NY, June 1988.

Invited paper presented in Columbus, Ohio at joint IEEE Antennas and Propagation and Microwave Theory and Techniques Chapter Meeting on "Application of GTD to Prediction of Terrain Effects on Radio Propagation Loss," June 1988.

Invited paper presented in Dayton, Ohio at joint IEEE Antennas and Propagation and Microwave Theory and Techniques Chapter Meeting under IEEE AP-S Distinguished Lecturer Program. Paper entitled "Application of GTD to Prediction of Terrain Effects on Radio Wave Propagation," June 1988.

LIST OF ALL PARTICIPATING SCIENTIFIC PERSONNEL SHOWING ANY ADVANCED DEGREES EARNED BY THEM WHILE EMPLOYED ON THE PROJECT

Raymond Luebbers

Randall Lasiter

William Foose - Received MSEE December 1986

Michael Schneider - Received MSEE December 1987;
PhD December 1988

Gregory Reyner - Received MSEE May 1988